1 class day

Lab 1: Introduction to Laboratory Equipment

For this first lab you will be working individually. When you enter the lab, please find a bench that is not occupied. You will only be allowed one class period to work on this lab. You must hand in your answers to the tasks contained in this lab at the end of class.

This lab is easy to complete in 3 hours, if you have read the lab in advance.

I. The Breadboard

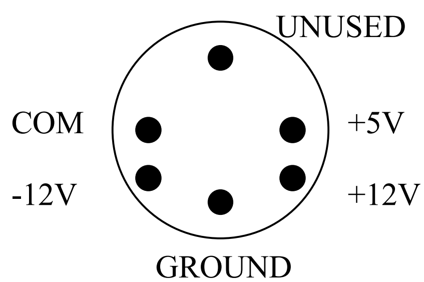
We will be watch the first video. You will need headphones for the computer.

Introduction to Breadboard, Part 1 (8 min):
    http://www.youtube.com/watch?v=oiqNaSPTI7w

Optional: How Breadboards Work (10 min):
    http://www.youtube.com/watch?v=lqw6ask5HK0

II. The DC Power Pack

There are two DC power supplies on your bench. The first is the black box sitting on your desk. The power supply is plugged in to the connector on the breadboard platform. The wires coming out of the back end of the breadboard connector are as follows:



GROUND is a direct connection to the Earth through the ground terminal on the three-prong wall plug. COM stands for Common Ground. It is the reference point from which the other voltages (+5V, ±12V) are measured. COM is a "floating" reference point. . "Floating" means it is not connected to Earth ground.

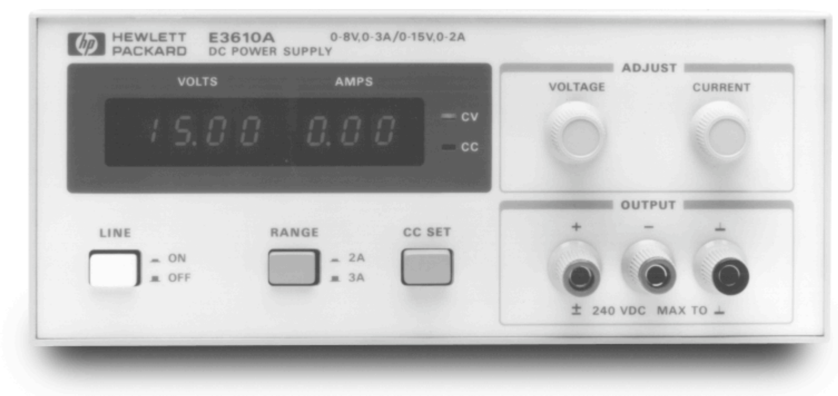
All four terminals (+5V, ±12V, and COM) are isolated by a transformer, whose secondary windings power the circuitry that generates the output voltages. In fact, COM can be biased by a different power supply to any potential (up to 30V

or so) and the three output voltages will likewise follow.

The key thing to note is that the output voltages are relative to the floating COM terminal and not to the GND terminal. Thus, for all the labs it is recommended to connect the COM terminal to the GND terminal.

Each voltage from the DC power pack (+5V, ±12V) is sent through a separate fuse on the breadboard mount. Make sure you only make connections to the supply voltage after the fuse. In the case of a wiring error, the fuse will blow, thus saving the power supply from possible damage. **We do not provide an unlimited supply of replacement fuses.** Please check your circuits very carefully before connecting to power!

The second DC power supply is the HP E3616A:



There are two knobs on the right: Voltage, and Current. These are used to adjust the constant voltage output by the device, or the constant current output by the device, if used as a current source. The three jacks on the front panel are the positive (red, left), negative (black, middle), and ground (green, right) outputs. These jacks allow for easy connections to a banana plug or a wire. To connect a wire you unscrew the grey covering of the jack a few turns, thread a wire through the hole in the jack connector post, and tighten the covering again. You can then connect the wire to your breadboard. For constant voltage mode, the current knob must be turned to a setting above any that need be supplied and then the voltage knob is set for the desired voltage. For constant current mode, the voltage knob must be turned to a setting above any that need be supplied and then the current knob is set for the desired current. The potential at the red terminal is always above that at the black terminal by the amount shown on the readout, but this potential difference is, like the power pack, floating. If the black terminal is wired to the green ground the red terminal will be at the potential given on the readout. If the red terminal is wired to this ground, the black terminal will be at a potential equal to the negative of the readout.

The supplies may already have the black terminal grounded (with an easy to miss wire between them) for using the red terminal as a positive supply voltage.

The rest of this lab will require you use a +5V source to explore various equipment. Please alternate between the power pack and the HP supply to gain experience using both.

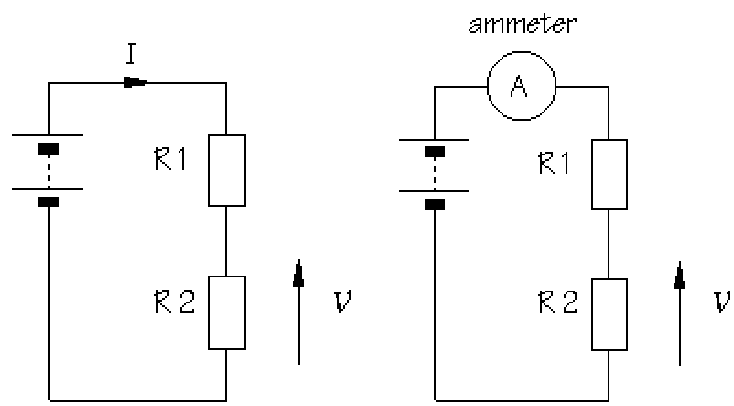
III. The Multimeter

(Taken in part from www.doctronics.co.uk)

A. What do meters measure?

A meter is a measuring instrument. An **ammeter** measures current, a **voltmeter** measures the potential difference (voltage) between two points, and an **ohmmeter** measures resistance. A multimeter combines these functions, and possibly some additional ones as well, into a single instrument.

Before going in to detail about multimeters, it is important for you to have a clear idea of how meters are connected into circuits. Diagrams A and B below show a circuit before and after connecting an ammeter:

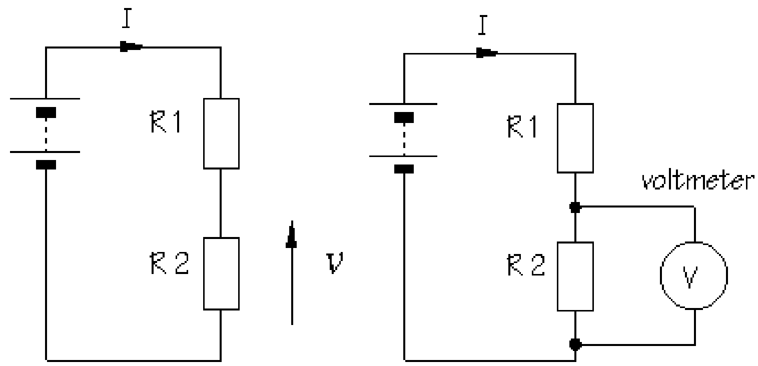


Left: Diagram A. Right: Diagram B.

To measure current, the circuit must be broken to allow the ammeter to be connected in series. Ammeters must have a LOW resistance.

Think about the changes you would have to make to a practical circuit in order to include the ammeter. To start with, you need to break the circuit so that the ammeter can be connected in series. All the current flowing in the circuit must pass through the ammeter. Meters are not supposed to alter the behavior of the circuit, or at least not significantly, and it follows that an ammeter must have a very LOW resistance.

Diagram C shows the same circuit after connecting a voltmeter:



Left: Diagram A. Right: Diagram C.

To measure potential difference (voltage), the circuit is not changed. The voltmeter is connected in parallel. Voltmeters must have a HIGH resistance

This time, you do not need to break the circuit. The voltmeter is connected in parallel between the two points where the measurement is to be made. Since the voltmeter provides a parallel pathway, it should take as little current as possible. In other words, a voltmeter should have a very HIGH resistance.

An ohmmeter does not function with a circuit connected to a power supply. If you want to measure the resistance of a particular component, you must take it out of the circuit altogether and test it separately.

To measure resistance, the component must be removed from the circuit altogether. Ohmmeters work by passing a current through the component being tested.

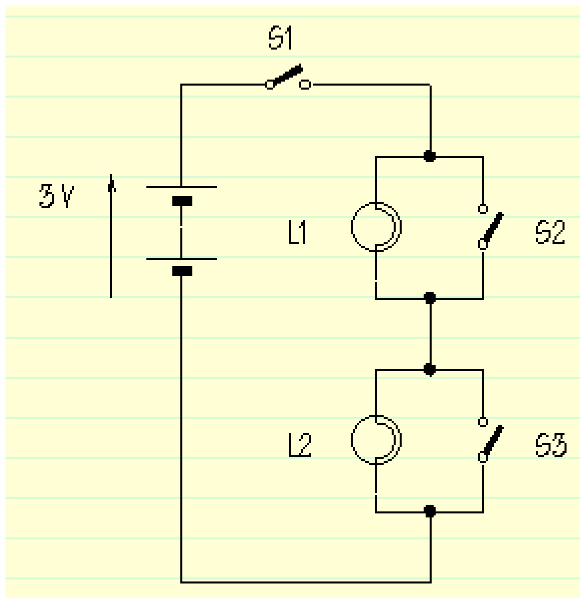
If you try this with the component connected into a circuit with a power supply, the most likely result is that the meter will be damaged. Most multimeters have a fuse to help protect against misuse.

Questions, Part III A:

1. If the potential difference (voltage) across a wire is constant, reducing the resistance of the wire causes the current to . . . ?

2. If the potential difference (voltage) across a wire is increased, without changing its resistance, the current will . . . ?

3. In the circuit below, which switches should be closed . . .



(A) to light lamp L1 only?
(B) to light lamp L2 only?
(C) to light lamps L1 and L2?

4. What would happen to lamps L1 and L2 if switches S1, S2 and S3 were all closed at the same time? Why should closing all three switches be avoided?

B. Digital multimeters

The diagram below shows a switched range multimeter, very similar to the ones we use in the lab:

The central knob has lots of positions and you must choose which one is appropriate for the measurement you want to make. For volt measurements, you should have the - connected into the COM input, and the + connected to V. If the meter is switched to 20 V DC, for example, then 20 V is the maximum voltage that can be measured. A display value of 1 means that the value you're trying to measure is too high with respect to the knob position (max allowed measured value). Try turning the knob to get a higher max range.

DC ranges are indicated by V--- on the meter. DC means direct current: current flow is always in the same direction. AC means alternating current: current reverses, or alternates, in direction. AC ranges are indicated by V~ on your multimeter.

For current measurements, you should have - connected to the COM input, and the + connected to mA. The dial should be switched to A--- for DC.
The current measurement components of the multimeter contain overload protection fuses. If no current measurements are possible, your fuse may be blown.

Always connect the COM to ground(-) before connecting your + to the multimeter!

When an ammeter is placed in series with a circuit, it ideally drops no voltage as current goes through it. In other words, it acts very much like a piece of wire, with very little resistance from one test probe to the other. Consequently, an ammeter will act as a short circuit if placed in parallel (across the terminals of) a substantial source of voltage. If this is done, a surge in current will result, potentially damaging the meter

Ammeters are generally protected from excessive current by means of a small fuse located inside the meter housing. If the ammeter is accidentally connected across a substantial voltage source, the resultant surge in current will blow the fuse and render the meter incapable of measuring current until the fuse is replaced. **Be very careful to avoid this scenario! We do not provide an unlimited supply of replacement fuses.**

You may test the condition of a multimeter's fuse by switching it to the resistance mode and measuring continuity through the test leads (and through the fuse). Connect the red lead to V and the black lead to mA. Touch the leads together. A high resistance (off-scale) indicates a blown fuse. A low resistance means the fuse is still good. When in doubt, please ask the instructor.

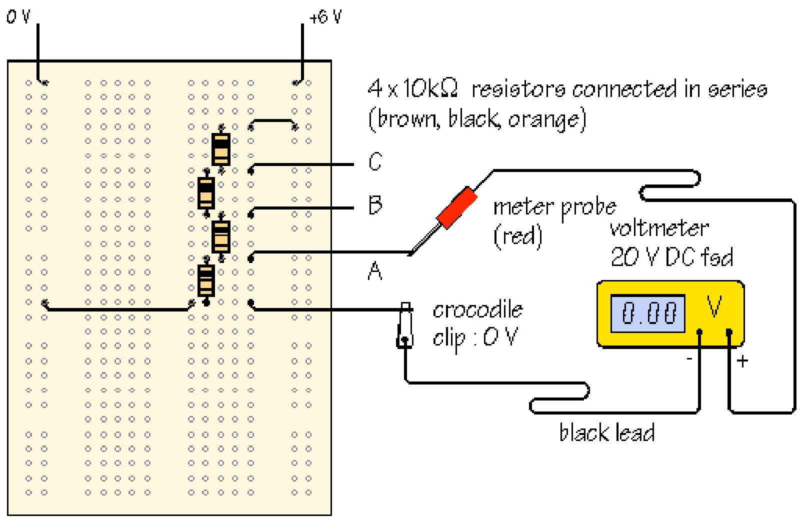
C. Making measurements

1. Voltage measurements:

The first task is to verify that the fuses on the back of the breadboard are all working, and that you know how to use the multimeter to test the three voltages coming out of the black DC power box (+5, +12, -12).

- Connect the black box DC power supply to your breadboard.
- Connect the COM wire from the breadboard to the COM hole in your multimeter using the alligator clip wires.
- Connect one of the three fused wires to the V hole in your multimeter using the alligator clip wires.
- Turn the multimeter knob to 20V DC.
- Turn the multimeter on.
- Record the measurement. If you don't see any value, please check you're your power supply is turned on. Repeat for the other two fused wires on the back of the breadboard.

Next, build the circuit shown below using prototype board and four 10 resistors:



We're really using a +5V power supply, provided by either DC power supply. Using the multimeter as a voltmeter, measure the power supply voltage and then measure the voltages at points A, B and C.

Question IIIC, 1: What do you notice about your results?

The four resistors are connected in series, making a chain known as a voltage divider. The total voltage is shared between the four equal resistors and, allowing for tolerance, each resistor receives an equal share.

Modify the circuit, replacing one or more of the four resistors with 1K or 100K values.

Question IIIC, 2 : Record the resistor value(s) you used as a replacement and remeasure the voltages at A, B, and C. Explain your results.

2. Resistance measurements:

Remove one of your resistors from the circuit and measure its resistance. To get the multimeter to function as an ohmmeter you will need to select an appropriate resistance range.

You can check the value of any fixed value resistor in the same way, and confirm that you have worked out the color code correctly.

Question IIIC, 3: Record the expected value of your resistor, and your measured value. What is the percent deviation between the measured and color code resistance?

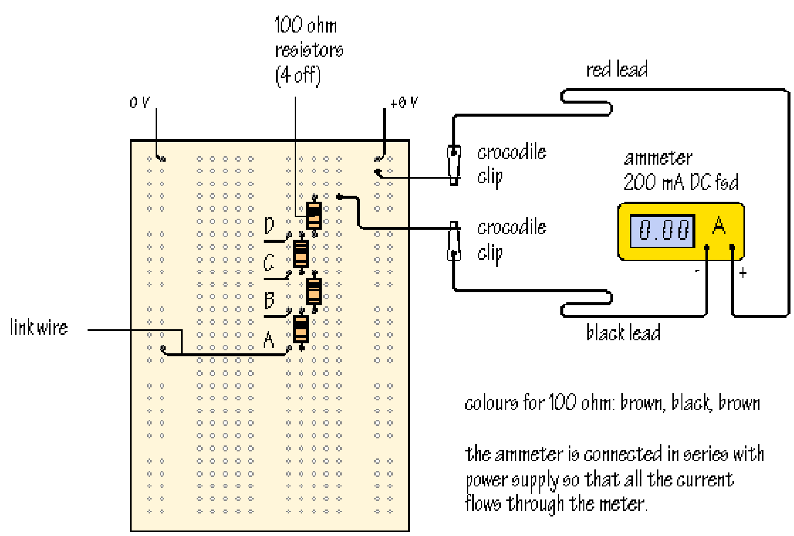
Percent deviation: ((lmeasured – expectedl / expected) * 100)

Small variations, up to ±5%, can be attributed to the tolerance of the resistors.

Question IIIC, 4: By what percent do your measurements vary? Are they all within 5% of each other?

3. Current measurements:

The diagram below shows a prototype board set up for the measurement of current:



Remember, we're using +5V. Note that the current must flow through the ammeter in order to flow through the resistors.

Question IIIC, 5: Take a reading of the current with the link wire to 0 V in position A. Write down the current value you observe. Take new readings after moving the link to positions B, C and D and record your observations. Don't forget to write in the measurement units of your answer. As the resistance increases the current decreases. Calculate the current expected in each case using the formula V= IR.

IV. The Oscilloscope

(Taken in part from Hands-On Electronics, Kaplan and White)

With its many switches and knobs, a modern oscilloscope can easily intimidate the faint of heart, yet the scope is an essential tool for electronics troubleshooting and you must become familiar with it. Accordingly, the rest of this laboratory session will be devoted to becoming acquainted with such an instrument and seeing some of the things it can do.

The oscilloscope we use is the Tektronix TDS210.

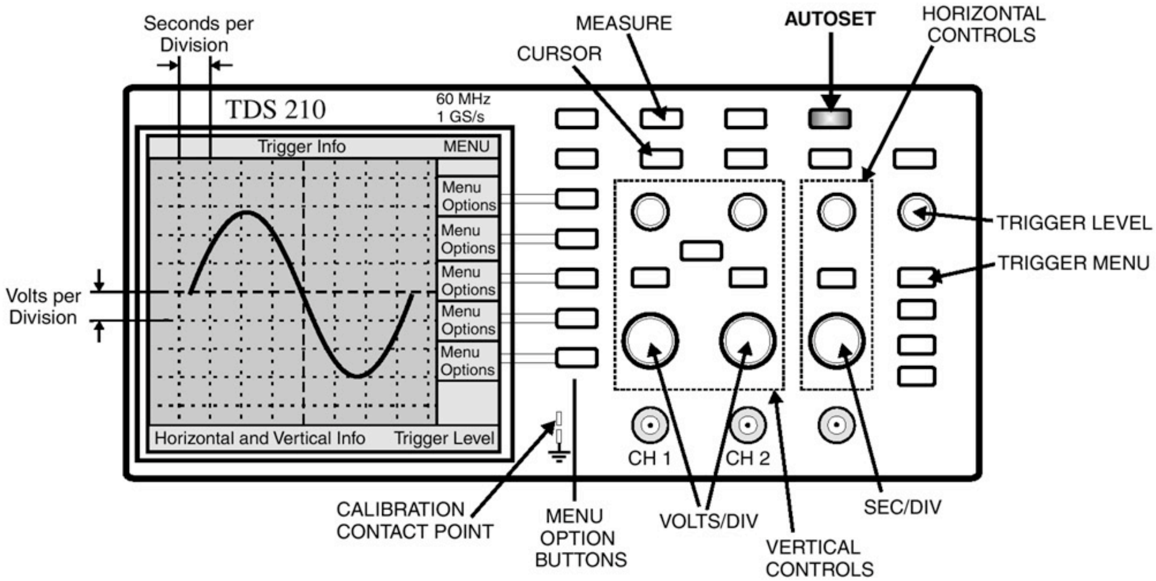


Illustration of the Tektronix TDS210 digital oscilloscope. The basic features to be used in this tutorial are marked. Note and remember the location of the 'AUTOSET' button – when all else fails, try autoset!

A digital scope operates on the same principle as a digital music recorder. In a digital scope, the input signal is sampled, digitized, and stored in memory. The digitized signal can then be displayed on a computer screen.

One of your first objectives will be to set up the scope. After that, you can learn about multiple traces and triggering. Start by using the built-in "calibrator" signal provided by the scope on a metal contact labeled "Probe Comp", located near the lower right-hand corner of the display screen.

A. Probes and probe test

Oscilloscopes come with probes: cables that have a coaxial connector (similar to that used for cable TV) on one end, for connecting to the scope, and a special tip on the other, for connecting to any desired point in the circuit to be tested. To increase the scope's input impedance and affect the circuit under test as little as possible, we generally use a '10X' attenuating probe, which has circuitry inside that divides the signal voltage by ten. Some scopes sense the nature of the probe and automatically correct for this factor of ten; others (<u>such as the TDS210</u>) need to be told by the user what probe attenuation will be.

Your scope has a built-in 'calibrator' circuit that puts out a standard square wave you can use to test the probe. The probe's coaxial connector slips over the 'CH 1' or 'CH 2' input jack and turns clockwise to lock into place. The 'CH 1' and 'CH 2' menu buttons can be used to turn the display of each channel on or off; they also select which control settings are programmed by the push-buttons just to the right of the screen. **You must have the Probe setting on 10X when you are using the probe!** The probe tip has a spring-loaded sheath that slides back, allowing you to grab the calibrator-signal contact with a metal hook or 'grabber'.

An attenuating scope probe can distort a signal. The manufacturer therefore provides a 'compensation adjustment' screw, which needs to be tuned for minimum distortion. The adjustment screw is located on the assembly that connects the probe to the scope. Display the calibrator square-wave signal on the scope by hooking the probe tip to the Probe Comp. (If you have trouble achieving a stable display, try 'AUTOSET'.) Carefully adjust the probe compensation using a small screwdriver and try to observe the overshoot and undershoot at the transitions in the square wave. Adjust the screw to where the overshoot is just barely eliminated.

<u>**Question IV A, 1: Check two probes. Make sure that both probes work, are properly compensated, and have equal calibrations. Sketch the observed waveform. Include the values for CH1, CH2, and M at the bottom of the screen.**</u>

Note that each probe also has an alligator clip (sometimes referred to as the 'reference lead' or 'ground clip'). This connects to the shield of the coaxial cable. It is useful for reducing noise when looking at high-frequency (time intervals of order nanoseconds) or low-voltage signals. Since it is connected directly to the scope's case, which is grounded via the third prong of the AC power plug, it must never be allowed to touch a point in a circuit other than ground! Otherwise you will create a short circuit by connecting multiple points to ground, which could damage circuit components.

This is no trouble if you are measuring a voltage with respect to ground. But if you want to measure a voltage drop between two points in a circuit, neither of which is at ground, first observe one point (with the probe) and then the other. The difference between the two measurements is the voltage across the element. During this process, the reference lead should remain firmly attached to ground and should not be moved! (Alternatively, you can use two probes and configure the scope to subtract one input from the other.)

Warning: A short circuit will occur if the probe's reference lead is connected anywhere other than ground.

B. Display

Your oscilloscope user's manual will explain the information displayed on the scope's screen. Record the various settings: timebase calibration, vertical scale factors, etc.

Question IV B, 1: Explain briefly the various pieces of information displayed around the edges of the screen.

C. Vertical controls

There is a set of vertical controls for each channel. These adjust the sensitivity (volts per vertical division on the screen) and offset (the vertical position on the screen that corresponds to zero volts).

Question IV C, 1: Display a waveform from the calibrator on channel 1. What happens when you adjust the POSITION knob? The VOLTS/DIV knob?

D. Horizontal sweep

To the right of the vertical controls are the horizontal controls. Normally, the scope displays voltage on the vertical axis and time on the horizontal axis. The SEC/DIV knob sets the sensitivity of the horizontal axis, i.e. the interval of time per horizontal division on the screen. The POSITION knob moves the image horizontally on the screen.

Question IV D, 1: How many periods of the square wave are you displaying on the screen? How many divisions are there per period? What time interval corresponds to a horizontal division?

<u>Question IV D, 2: Adjust the SEC/DIV knob to display a larger number of periods. Now what is the time per division? How many divisions are there per period?</u>

E. Triggering

Triggering is probably the most complicated function performed by the scope. To create a stable image of a repetitive waveform, the scope must ‘trigger’ its display at a particular voltage, known as the trigger ‘threshold’. The display is synchronized whenever the input signal crosses that voltage, so that many images of the signal occurring one after another can be superimposed in the same place on the screen. The LEVEL knob sets the threshold voltage for triggering.

You can select whether triggering occurs when the threshold voltage is crossed from below (‘rising-edge’ triggering) or from above (‘falling-edge’ triggering) using the trigger menu (or, for some scope models, using trigger control knobs and switches). You can also select the signal source for the triggering circuitry to be channel 1, channel 2, an external trigger signal, or the 120 V AC power line, and control various other triggering features as well.

Since setting up the trigger can be tricky, the TDS210 provides an automatic setup feature (via the AUTOSET button) which can lock in on almost any repetitive signal presented at the input and adjust the voltage sensitivity and offset, the time sensitivity, and the triggering to produce a stable display.
In normal trigger mode, the scope acquires new readings only on a valid trigger (you can see the ready/trigger indicator at the top of the display change to trigger on a valid trigger. Auto mode works like normal mode when valid triggers are present, but switches to free running mode when triggers are not present.

<u>Question IV E, 1: After getting a stable display of the calibrator signal, adjust the LEVEL knob in each direction until the scope just barely stops triggering. What is the range of trigger level that gives stable triggering on the calibrator signal? How does it compare with the amplitude of the calibrator waveform? Does this make sense? Explain.</u>

F. Coupling

DC coupling means that whatever voltage is connected to the scope input will be displayed; this is usually what you want. AC coupling places a capacitor in series with the input which blocks any DC voltage in the input waveform. Sometimes

this is handy to see a small signal on top of a constant offset. The ground setting just shows you where zero volts is on the display and does not ground the input lead.

Question IV F, 1: Try looking at the calibration square wave as you change the coupling from DC to AC and describe the changes in the scope display.

V. The Function Generator

Next connect the scope to the function generator using a co-axial (BNC) cable. Connect the cable to the FUNC OUT connector on the front panel of the function generator.

Turn the generator on. This automatically produces a 1000 KHz, 1V peak to peak, sine wave. Adjust your scope accordingly to see the sine wave.   Notice the 50Ω on the left side of the function generator is green. The factory default assumes a 50Ω load. Accordingly, the function generator supplies a voltage that would produce the desired waveform in a 50Ω load. If your actual load differs from 50Ω, the waveform at your load will differ from the desired waveform. In this class you should always use the HIGH-Z setting of the function generator. To change to HIGH-Z, press the SHIFT/MHz key once (SHIFT will be lit), and then press the number 6. Note that if the menu is set to 50Ω and the actual load is high impedance, the voltage that appears across the high impedance load will be 2 times the voltage shown on the display.

The function generator's amplitude and frequency are adjusted by means of the FREQ and AMPL buttons.

<u>Question V 1: Look at each of the waveforms available from the function generator: square, sine, and triangle. Try out the frequency and voltage controls and explain how they work.</u>

Adjust the function generator's frequency to about 1 kHz. Display both scope channels, with one channel looking at the output of the function generator and the other looking at the scope's calibrator signal. Make sure the vertical sensitivity and offset are adjusted for each channel so that the signal trace is visible.

<u>Question V 2: What do you see on the screen if you trigger on channel 1? On channel 2?</u>

<u>Question V 3: What do you see if neither channel causes triggering (for example, if the trigger threshold is set too high or too low)?</u>

<u>Question V 4: How does this depend on whether you select 'normal' or 'auto' trigger mode? Why? (If you find this confusing, be sure to ask for help, or study the oscilloscope manual more carefully.)</u>

The TDS210 oscilloscope has many more features than the ones described so far. Particularly useful are the digital measurement features. Push the MEASURE button to program these. You can use them to measure the amplitude, period, and frequency of a signal.

Using the measurement features, determine the amplitude, frequency, and period of a waveform of your choice from the function generator.

<u>Question V 5: Explain which waveform you used, the settings on the function generator for amplitude and frequency, how you made these measurements and what your results were.</u>

You can also use the on-screen cursors to make measurements. Use the cursors to measure the half-period of the signal you just measured.

<u>Question V 6: Explain how you made these measurements and what your results were.</u>

A feature that comes in particularly useful on occasion is signal averaging; this is programmed via the ACQUIRE button and allows noise, which tends to be random in time, to be suppressed relative to signal, which is usually periodic.